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RESEARCH PAPER

Log Characteristics and Sawn Timber Recovery of Home-Garden Teak from Wet and Dry Localities of Kerala, India

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Abstract There is a widely held view among smallholders that teak timber produced from small-scale agroforestry systems, especially home-garden forestry, fetches a lower price than that from conventional plantation forestry. To examine the veracity of this view, the wood quality attributes of teak from two home gardens in the district of Ernakulam (wet site) and Palakkad (dry site) in India were compared to those of forest plantation in Nilambur. The logs were graded using standard timber trade practices into high, medium and low quality as determined by the potential sawn timber grade-yield recovery pattern. Of 96 home garden teak logs (aged 35 years) from wet and dry sites, 59% belonged to timber Grade II–IV and the rest were classified as poles. Grade I logs (export quality) with a girth above 150 cm were not available from either of the homesteads. Faster-grown teak in the wet site produced large diameter logs (dbh 1.37 m) with average diameter of 39.6 cm, which is comparable to that of best site quality in India. In contrast, the average dbh for teak grown in the dry site was 24 cm as compared to the average dbh of 31 cm recorded from the same aged forest plantation in Nilambur. It was found that only 10% of logs belonged to Grade II timber and the rest fell under grades III and IV with more frequent visual defects. The sawn timber recovery percentage was lower for the dry site (66.8%), whereas there was no significant difference in grade from the wet and forest plantation sites, with recovery rates of 76.5% and 78.8%, respectively. The general notion that home garden teak has a large proportion of sapwood seems to be baseless, no significant difference being found between the heartwood-sapwood ratio of home-garden and forest plantation teak. Lack of appropriate silvicultural practices in home-garden forestry caused the production of more defective logs, adversely affecting the market price of timber.

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Introduction

Teak (*Tectona grandis* L. f.), the world's most cultivated high-grade tropical hardwood, grows naturally on over 23 M ha in India, Myanmar, Laos and Thailand. Teak cultivation is not uncommon in many parts of the world, including Indonesia, Western Africa, the Caribbean, South and Central America and Northern Australia (Bhat and Ma 2004). Teak is a high-priced wood because of its golden brown colour, straight grain and attractive figure, greater dimensional stability, medium strength and high natural durability.

Teak is an important tree crop in home garden forestry in Southern India, particularly Kerala. The term *home-garden forestry* is used in this study to refer to the practice of growing trees in combination with various agricultural crops around homesteads, as a kind of agroforestry practice (Nair 1989). The felling cycle for home garden teak in India is typically about 30–35 years, as against the traditional rotation of 50 years or more. With the ever-increasing demand for this high quality timber, many farmers started teak cultivation in home gardens as a short-rotation tree crop to meet their financial and domestic wood requirements, as an important element of farm livelihoods (Dewees and Saxena 1997). In home gardens, once teak trees are planted there is little proactive management—little fertilizer application, weeding, pruning or thinning to obtain knot-free clear boles. If these activities are undertaken they are usually intended to benefit other agricultural crops. Farmers often plant and manage teak trees without a specific market or product in mind, hence teak timber from the homesteads is often sub-standard in quality and fetches a relatively low price. Anyonge and Roshetko (2003) suggested that farmers should be trained basic management practices for targeting the market for high quality production of teak timber at farm level.

Both farmers and traders have a general notion that home garden teak is paler in colour, poor in log form, smaller in size, less durable and the sawn timber recovery rate is low, when compared to the teak produced from forest plantations. Teak logs from areas with high rainfall are less favoured than logs from low rainfall areas in terms of aesthetic qualities. It has been demonstrated that pruning can increase the volume of knot-free straight bole by over 40% in a 20-year-old teak plantation in Costa Rica, with increased heartwood volume (Víquez and Pérez 2005). Bhat et al. (2005) reported that home garden teak produced in 'wet' sites' (high rainfall area) is highly susceptible to attack by brown-rot fungi. Also, the wood is paler in colour and more yellowish (Thulasidas et al. 2006). Pérez and Kanninen (2005) reported that 'wet' site faster-grown plantation teak produces less heartwood than slow-grown teak in a 'dry' site (low rainfall area) in Costa Rica. Bhat et al. (2001) reported that the rotation period of fast-grown teak can be reduced without affecting particular wood properties, including timber strength.

Balasundaran and Gnanaharan (1997) studied the timber defects of plantation-grown teak and their implications on wood quality. They reported that when the

percentages of logs under various grades for teak logs were considered, plantation teak from Konni in Kerala were the best quality, because 70% of the logs came within the three grades (Grade I to III) and about 30% in Grade I alone. Apart from this, no adequate information is available with regard to the quality of teak logs produced from homestead plantings. Of the total annual production of 11.7 M m^3 of wood in Kerala State for the year 2000–2001, homesteads contributed about 75% (Krishnankutty et al. 2005), and teakwood alone contributed 33%. Considering the major share of teakwood in the market in Kerala, quality assessment of home garden teak logs is imperative for the judicious utilisation of this valuable resource.

Because of the importance of teak as a farm-grown timber, this study explores the quality concerns of homestead teak by farmers and traders. No science-based recommendations are available in the literature to produce high quality timber from homesteads by adopting appropriate management practices. Such practices (thinning, pruning and weeding) are carried out by the farmers, in most cases, based on visual assessment and common sense. Because of their poor knowledge of tree management and often sub-standard quality of their products, farmers are at disadvantage when negotiating with traders who come to villages in search of trees to fell and are often compelled to compromise on the price of teak. The average price of home garden teak logs in the domestic market falls in the range of US$ 675–975/m^3 as against US$ 1100–1500 for plantation teak logs. This price difference may also be influenced by the government policies regulating felling and marketing of teak grown on private land in India. Often farmers in order to avoid the bureaucratic hassles are forced to sell teak to middlemen, who pay relatively low prices. The objectives of this study is therefore to evaluate the wood quality of teak produced in the homesteads of high and low rainfall areas of Kerala, India, in terms of the merchantable log size, visual defects, sapwood-heartwood proportion, sawn wood volume and recovery rates.

Study Site and Research Method

In Kerala, teak thrives in the moist, warm, tropical climate, especially in well-drained alluvial soils with an annual rainfall between 1000 and 3500 mm in areas up to 1000 m above sea level. A farm level survey was undertaken to locate the availability of merchantable home garden teak trees of age 30–35 years. Studies were conducted in the year 2003 in a location where teak is predominantly grown as tree crop in the homesteads representing high rainfall site (Muvattupuzha) and low rainfall site (Nemmara). Characteristics of these sites, and the forest plantation site at Nilambur, are summarized in Table 1.

A large quantity of logs from the two home garden sites is currently processed for domestic consumption and marketing. Hence, the above two localities were selected for log characterization and grading as per the Indian Standard IS 4895[1] (BIS 1968). Since farmers fell trees when they attain minimum harvestable size at about

[1] This standard covers the requirements of various grades of teak logs intended for conversion purposes based on the estimated sawn timber recovery; it does not cover teak logs for veneering purposes.

Table 1 Environmental conditions and size of sampled teak trees from wet and dry localities as compared to forest plantation at Nilambur, Kerala

Factor	Wet site (Muvattupuzha), Ernakulam district	Dry site (Nemmara), Palakkad district	Forest plantation (Nilambur)
Altitude (masl)	20	40	60
North latitude	9° 59′	10° 35′	11° 15′
East longitude	76° 34′	76° 35′	76° 13′
Soil type	Loamy sand	Loamy sand	Loamy sand
Annual rainfall—range mm	2500–3500	1500–2300	2500–3000
Annual mean temperature—range °C	17–34	26–37	17–37
Mean annual relative humidity (%)	Above 80	70	70
Mean tree height (m)	17.0	14.0	21.0
Mean diameter at breast height, dbh (cm)	39.6	24.0	31.0

Table 2 Classification and grading of teak logs from homesteads based as per Indian standard

Teak timber class	Girth limits (cm)	Length (m)	Number of logs in each grade[a]			Number of logs graded in the homesteads	
			A	B	C	Wet	Dry
1	>150	>3	–	–	–	–	–
II	>100–149	>3	3	3	4	7	3
III	>76–99	>3	7	9	6	7	15
IV	65–75	>3	6	10	9	5	20
Total			16	22	19	19	38

[a] Logs of 3 m length with not more than 2.5 units of defects are considered Grade I, logs that contain not more than 5 units of defects fell under Grade II, logs with 7.5 units are considered Grade III, and above 7.5 units, Grade IV

35 years, logs of this age only were included for grading. A total of 96 selected logs were graded from the above two home garden localities soon after the trees were felled, before transporting to local sawmills; the grade distributions are reported in Table 2. Coppiced trees were not selected for this study because they differ in tree growth performance and stem quality (Bailey and Harjanto 2005).

Measurement and evaluation of defects was based on permissible visual defects including sound or unsound knots, straightness of the log, heart rot, and checks and flute, as per the Indian Standard IS 3364 (BIS 1976). Grading rules are based mostly on visual assessment, i.e. on quality characteristics including natural defects and heartwood colour. Defects have been grouped by type and are evaluated in units with regard to size and its distribution in the logs. The permissible visual defect units were recorded according to the location and magnitude of occurrence in the main bole. The defect values apply to individual logs and not to log consignments as

a whole. Defects have a value ranging from 0.5 to 1 unit depending on the extent or degree of the defect. For example, sound knots measuring over 10–15 cm in diameter and occurring not more than 4 in number in a length of 3 m, were taken as 1 unit. Each log was graded separately, based on the grading rules for teak logs (as described in BIS 1968). Teak timber and poles are classified differently in various states of India depending upon their utilisation.

Five defect-free home garden teak trees (aged 35 years) were felled from each of the wet and dry localities for the estimation of sawn timber recovery. These trees were not subjected to any proactive management practices such as pruning or thinning except that branches were removed when impeding the growth of agricultural crops. For comparison, five dominant teak trees of the same age were chosen from a typical forest plantation at Nilambur, famous for the *Malabar Teak*, where periodic silvicultural practices (weeding, pruning and thinning) are undertaken by the Forest Department. Border trees were excluded in the selection for felling of sample teak trees to eliminate the border effect of growth. For estimating sawn wood recovery rate, logs collected from the three sites were transported to the laboratory and processed in the sawmill. The basal butt log of one-metre length (above stump level) was used for this study, and above breast height level material utilised for strength and durability testing. The method of flat sawing (tangential sawing) was adopted to achieve maximum recovery. Sawn timber output (in m^3)[2] and recovery percentage (ratio of sawn timber output over log volume) were calculated based on the commercial quarter girth formula recommended in Indian standard specifications. A one-way analysis of variance (ANOVA) followed by Duncan's multiple range test ($P < 0.05$) was used to compare sawn timber output and recovery rates between the home garden and plantation-grown teak.

In order to assess the sapwood width and sapwood-heartwood ratio, 5 cm thick cross-sectional discs from each log were removed at breast height (1.37 m) from logs from the three localities. Sapwood width was measured in the cross-sectional area of the discs at four radii, at right angles to each other, and the four measurements were averaged. Sapwood-heartwood proportion was measured in the same way. The same wood discs were used for measuring the wood density. A diametrical segment was removed from each disc to measure basic wood density calculated as the oven-dry weight of the sample divided by its green (undried) volume. One-way ANOVA was used to test the significance of sapwood–heartwood proportion and basic density between the home garden and plantation-grown teak.

Results

Log Quality

Of the total of 96 logs graded (Tables 2 and 3), Grade I timber of export quality was not available from either of the two areas of homesteads, because girth of the logs

[2] Sawn timber output was estimated as $V = (G/4)^2 \times L$, where V = volume of log in m^3, G = girth (mid-girth below bark), and L = length of log in m.

Table 3 Classification of teak poles from homesteads after grading

Pole class	Girth limits (cm)	Length (m)				Number of poles in each grade[a]				Number of poles graded in the homesteads	
		A	B	C	D	A	B	C	D	Wet	Dry
1	(65–75)	>12	9–12	6–9	3–6	–	–	1	2	–	3
II	(53–64)	>12	9–12	6–9	3–6	1	1	3	2	–	7
III	(41–52)			>6		–	–	5	–	–	5
IV	(28–40)				>6	–	–	–	12	–	12
V	15–27)				<6	–	–	–	12	6	6
Total						1	1	9	27	6	33

[a] The same grading system is followed as used in Table 2

fell short of 150 cm. The home-garden teak from the wet site produced timber of average dbh of 39.6 cm and from the dry site only small dimension timber of average dbh 24.0 cm. The average dbh in the same aged Nilambur forest plantation was 31.0 cm (Table 1). Fifty-nine percent of the logs graded were of girth classes II to IV, and the rest were of pole class I to V (Table 3). Only 10% of logs were of Grade II timber. The rest fell under Grade III and IV as per the Indian standard, mostly due to the presence of visual defects such as flute, bend and unsound knots. The dry site home-garden teak qualified only to site quality (SQ) II and III with the major share falling under the pole classes (Table 3).

Sawn Timber Recovery

The sawn timber recovery rates are reported in Table 4. The ANOVA showed that sawn timber recovery was significantly lower for logs from the dry site (66.8%, $P < 0.05$) than from the wet site home garden and plantation teak (76.5% and 77.8%, respectively). Even though wet site teak had slightly larger diameter logs

Table 4 Comparison of mean sawn timber volume and recovery of teak wood from wet and dry homesteads and forest plantation based on 1-m length butt log of varying girth (CV% in parenthesis), $n = 5$ each

Location	Log length (m)	Log mid girth (m)	Log volume, quarter girth (m^3)	Sawn timber output (m^3)	Sawn timber recovery (%)
Wet	1	1.33^{a} (9.4)	0.111^{b} (18.0)	0.084^{c} (10.1)	76.5^{d} (10.9)
Dry	1	0.81^{e} (8.0)	0.041^{f} (15.8)	0.028^{g} (23.8)	66.8^{h} (8.2)
Forest plantation	1	1.05^{i} (2.8)	0.069^{j} (5.6)	0.054^{k} (3.4)	77.8^{d} (2.7)

Note: Cell values differing by a letter in the superscript within each column are significantly different at $P < 0.001$

Table 5 Relationship between mean heartwood percentage vs. diameter, sapwood width and basic wood density of teak from wet, dry and forest plantation sites (CV% in parenthesis), $n = 5$ each

Location	DBH (cm)	Heartwood (%)	Sapwood width (cm)	Wood basic density (kg/m^3)
Wet	39.6^a (9.7)	70.6^b (10.5)	2.9^c (32.1)	600^d (8.2)
Dry	24.0^e (8.6)	64.1^b (12.6)	2.2^c (34.5)	645^d (8.5)
Forest plantation	31.0^f (2.9)	72.8^b (5.5)	2.2^c (13.3)	597^d (2.8)

Note: Cell values differing by a letter in the superscript within each column are significantly different at $P < 0.001$

(39.6 cm), the recovery percentage did not differ significantly from the plantation teak (diameter 31.0 cm).

Sapwood Width and Heartwood–Sapwood Proportions

The mean sapwood width of the sampled logs (2.9, 2.2 and 2.2 cm) of 35-year-old home-garden teak and the same aged plantation teak did not differ significantly (Table 5).

The heartwood proportion, as measured at breast height, was 71%, 64% and 73% from wet, dry and forest plantation sites respectively. From the ANOVA, the heartwood-sapwood ratio did not differ significantly ($P > 0.05$) between the three locations even though the large diameter logs had a proportionately higher heartwood percentage than small diameter logs (Table 5). Wood basic density also did not differ significantly between the three localities.

Discussion

Log Quality

The log grading of the felled homestead teak trees revealed that visual defects such as bend, flute and knot size and frequency qualify the timber only for Grade II or III as per the Indian standard. The major defect noticed in the wet site teak was more frequent curvature in the main bole and occurrence of comparatively fewer sound knots. Knot-free large diameter logs similar to that of Site Quality 1 (SQ 1) prescribed in the All India Yield Table[3] (published in FRI and Colleges 1970) were obtainable from wet site homesteads (Table 2). Farm practices such as fertilizer application and irrigation to other agricultural crops might have indirectly contributed to faster growth resulting in higher log volume.

[3] The yield and volume table was prepared using the sample plots laid out throughout India where teak is grown as plantation species. For evaluating the performance of teak plantations, the actual mean yields were compared with the expected yields for different site quality classes. The site quality (SQ) is estimated based on the height and girth measurements. Based on the yields realised, the average SQ (I, II, III and IV) attained was addressed. The All India Yield Table gives the details of mean crop diameter, height and details of the mean yield for SQ I, II, III and IV respectively.

The frequency of unsound knots was higher in the small diameter logs due to the large branches, resulting from farmers planting of trees at wider spacing. Fluting and heart check were less pronounced. Water blister—a common form of defect in plantation teak causing radial shake in the trunk wood (Kallarackal et al. 1997), wherein healthy looking trees, mostly growing near watercourses were affected—was not found in homestead teak which are usually planted in smallholdings[4] with adequate drainage. The occurrence of bends at approximately one-third of total height of the tree canopy was noticed towards the basal log above breast height level (up to 10 m) in both wet and dry sites, probably due to the strong competition the teak trees had to face in the home gardens along with other tree crops planted by the farmers, teak being a prime light-demanding species. Because the farmers seldom practice any standard silvicultural or management methods or foresee any specific end-product for marketing, and are often unaware of the prevailing market price of home garden teak, they received very low prices in the timber market.

Sawn Timber Recovery

The major structural factors that determine sawn wood grade and recovery are size and frequency of unsound hollow knots, deep flutes in the log, stem size, bole shape, and heartwood-sapwood proportion (Bhat 1998a, b, 2000). Sangkul (1995) reported about 51% of sawn wood recovery from 20-year-old plantation teak trees with a diameter of 9–20.5 cm in Thailand. By adopting appropriate silvicultural thinning and pruning practices that reduce the incidence and diameter of knots, the lumber recovery and grading could be increased considerably, because logs of higher quality will result in a higher lumber recovery rate, as reported from Malaysia (Tze 1999). In spite of the low sawn timber recovery recorded for the dry site (Table 4), the timber's remarkable decorative features are preferred for manufacture of specialty products including decorative veneer, joinery and furniture, and can fetch a high price despite small log dimensions. Due to mixed cropping of teak with other tree crops and teak being an obligate light-demanding species, tension wood was prevalent in teak from both wet and dry home gardens. However, it was totally absent in the silviculturally managed monoculture plantation like teak where block planting in equal spacing of 2×2 m reduces the chances of tension wood occurrence and the trees grow straight as observed in this study. Sawn wood recovery and subsequent utilisation potential was not affected by the presence of tension wood.

Sapwood Width and Heartwood-Sapwood Proportions

The rotation length of plantation teak in India is 60–80 years, and the sapwood width of the large diameter logs of this age has a maximum of about 1–1.5 cm. The observed non-significant difference in sapwood width of the teakwood sampled from wet and dry home gardens indicates that farmers' choice to harvest the teak at

[4] Landholdings up to 0.5 ha are considered as smallholdings, and these account for over 74.4% of the home gardens in Kerala (Government of Kerala 2001).

short rotation does not adversely affect the quality parameters of the log. As trees mature, the width of the sapwood band remains more or less stable and the heartwood amount increases in teak (Bhat 2000). The mean sapwood proportions observed in 13 and 21-year-old plantation teak in Nilambur were 52% and 40%, in contrast to 16% and 15% in 55 and 65-year-old trees respectively (Bhat 1998b). Sapwood width decreases with tree age, and stabilizes for older trees, as observed in this study (Table 5). Wood basic density also did not differ significantly between the homestead and forest plantation sites. This implies that even though log quality is affected by the visual defects in homestead teak, its inherent wood density remains stable at maturity irrespective of the planted site, indicating the suitability of the timber for any structural applications.

Conclusion

The shorter rotation teak harvested from the homesteads was found to have wood qualities similar to mature teak except for poor log form and more frequent occurrence of visual defects. Farmers' inadequate management practices are partly responsible for the production of poor log form that resulted in low sawn timber recovery from the dry site, although these defects were less common in the wet site. Trees outside the forest (ToF) are now recognized by policy-makers, planners and managers as an essential component of sustainable development in Asia, Africa and Central America (FAO 2001). Adoption of standard silvicultural practices especially growing trees in square or rectangular homestead plots with closer initial spacement (say, 2 × 2 m) followed by mechanical or silvicultural thinnings would give better log form and fewer knots. The findings suggest that smallholders should not grow trees individually or in isolation without square or rectangular block plantings, if they are to avoid the log eccentricity with other visual defects including bends and knots. The need for intensive pruning to avoid low quality knotty timber, when trees are grown in isolation, is also apparent.

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